SIMULTANEOUS OCCURRENCE OF HALOS AND CORONAS

Dr. C. F. Brooks, in a short article published in the MONTHLY WEATHER REVIEW, January, 1919, **47**; 21, cites several cases in which lunar halos and coronas were visible at the same time. Starting with the assumption that coronas originate only from clouds formed of liquid particles, he admits that halos are due to clouds formed of solid particles; these, falling through an atmospheric stratum relatively warm, will pass into the liquid state; whence the origin of the corona. The author does not consider the possibility of supercooled water, nor the formation of coronas by transparent ice crystals.

The simultaneous occurrence of halos and coronas is a more frequent phenomenon than might be thought. In my researches on the frequency of halos I have found numerous cases of such simultaneity. But already Pernter in his "*Meteorologische Optik*," p. 424, cites 16 cases from observations from Ben Nevis, and 4 cases from the expedition of the "Belgica."

It is not necessary, therefore, to form any special hypotheses as to the physical state of the water, as Pernter demonstrates in the same work, p. 395,ffg., coronas may also form in clouds made up of particles in the solid state.—*Carlo Negro*, Torino, Italy. [Translation by *R. S. H.*]

Discussion.—Since the finest coronas are produced on clouds having temperatures far below the freezing point of water, Pernter assumed that such coronas were formed by the diffraction due to ice crystals. Simpson has pointed out, however (*Quar. Jour. Roy. Meteorological Soc.* 1912, **38**, 291–301), that the observations of the Ben Nevis and other meteorological logs referred to by Negro are merely cases in which coronas and halos were entered together, they do not prove that both were produced by one and the same cloud. Careful observations by Simpson while in the Antarctic failed to reveal a single instance in which a corona and halo were seen on the same cloud. Furthermore, his observations of a fog bow prove conclusively that liquid water droplets can exist at −29° C., and there is no reason to believe that this is the lower limit; hence the high clouds on which coronae are observed do not necessarily have to consist of ice crystals. In addition, Simpson shows that ice clouds could not produce coronae at all, merely white light.

Some instructive notes on the existence of minute undercooled *liquid* droplets in the atmosphere, and their relations to crystallization, will be found in *Symons's Meteorological Magazine*, 1917, vol. 52, pp. 17–18, 31–32. (In this connection it may be stated that the present writer has been informed by a competent crystallographer that certain minerals are known in which the surface tension so far overbalances the force of crystallization, even in finite crystals, that crystals with plane faces can not be produced, and in one instance solid *spherical* crystals were obtained.)

It is evident, therefore, that the simultaneous appearance of a halo and a corona requires some special explanation, as in the observations cited by Brooks. This problem, it should be noted, is totally distinct and different from that treated by S. W. Visser in a very important paper "On the diffraction of the light in the formation of halos," Kon. Ak. van Wetensch. te Amsterdam, *Proc. Sec. Sci.*, 1917, 19, pt. 2, pp. 1174–1196 (See abstract in MONTHLY WEATHER REVIEW, 1918, **46**, 22.)—*E. W. Woolard.*

Additional note.—The simultaneous occurrence of a solar halo and corona, or coronae, does not appear to be a rare phenomenon when two or three layers of clouds are involved.

In fact, the frequency is nearly as great as the frequency of halos, although not usually observable without dark glasses or mirror, and, therefore, seldom noticed, and even less often recorded. Occasionally, once or twice a month, a halo may be seen in cirro-stratus cloud, the lower portions of which envelop a corona-forming alto-cumulus layer. The halo may be complete, or nearly so, and with practically undiminished brilliance where it passes in front of alto-cumulus masses; and the denser parts of the alto-cumulus layer cast long shadows down through the cirro-stratus. Although such a halo and corona are not in the same cloud, one cloud and part of the other occupy the same space.—*C. F. Brooks.*

NOTES ON IRIDESCENT CLOUDS.

By S. FUJIWHARA and H. NAKANO.

[Abstracted from Journal of the Meteorological Society of Japan, June, 1920, vol. 39, No. 6, pp. 1–9.]

Pernter's theory of the diffraction of light by ice crystals would be valid if all the needles were so arranged that they had a definite direction, such as would happen if the cloud had some acceleration; this would, in general, be pretty rare, however.

Although the minute drops necessary for Simpson's theory of iridescent clouds are not included within the limits of sizes assigned by Pernter ($1\times10^{-3}<r<5\times10^{-3}$ cm.), the generalization by which Pernter derived these limits does not seem to be sound; and A. Wegener (*Met. Zeit.*, 1910, p. 354) has shown the possible existence of drops of radius 10^{-7} cm. If undercooling can take place to the extent postulated by Simpson, then the latter's theory can be correct. The irregular distribution of colors in iridescent clouds may be due to the irregular distribution of drops of various sizes.

Calculations of the lines of iridescence in the ideal cases of circular clouds and band clouds indicate that all observed hemming and crossing of clouds by color bands may take place with the proper distribution of suitably sized drops, such as presumably exists along the edges of forming or dissolving cloud. (See G. C. Simpson, *Quar. Jour. Roy. Meteorological Soc.*, 1912, 38, 291–301; C. F. Brooks, note below; W. J. Humphreys, *Jour. Franklin Inst.*, Nov., 1919, pp. 654–655.)

Furthermore, the cloud of vapor arising from a vessel filled with hot water shows beautiful diffraction effects when illuminated by sunlight, at angular distances up to 45°, proving the existence of sufficiently small drops. In this vapor, as along the edges of quickly forming (usually thin) clouds, the water drops are in an unstable state, and uniform in size within stratified layers. The violent turbulence, and formation of large drops, in a cumulus head explains why such colors are not observed in this case.—*E. W. W.*

IRIDESCENT CLOUDS.

By CHARLES F. BROOKS, Meteorologist.

[Weather Bureau, Washington, D. C., June 26, 1920.]

Forming, lenticular clouds often show well-defined alternating reddish and bluish or greenish color bands parallel to the edge of the cloud, the innermost portion being perhaps lighted with a greenish or reddish sheen, or perhaps both irregularly intermingled, over a relatively large area. These colors are usually most brilliantly developed within 30 degrees of the sun but at times (as at Washington, D. C. at 2:05 p. m. June 23, 1920) may be discernible to a distance of more than 50 degrees.[1]

[1] Faint diffraction color bands were observed parallel to the edge of a lenticular cloud, about 55° from the sun, at 6:30 p. m., July 26, 1920.

Diffraction, which forms the well-known coronas about the sun and moon, will for droplets of a certain size produce alternating red and blue rings to considerable angular distances from the luminary.[2] Recently I saw a solar corona with a set of four brilliant red rings at roughly equal intervals and interspersed with bluish rings. The larger the droplets, the smaller is the angular interval between successive rings of the same color and the smaller is the first ring around the sun or moon. Also, for any size of droplet, the angular interval between successive red rings decreases with increasing distance from the sun or moon. When the droplets are very small, as they must be in the lenticular clouds, the width of each red or blue ring is several degrees because the successive interference bands are so far apart. Thus an ordinary lenticular cloud may lie wholly within a red or blue band for very small drops. On the thin, sharp edge of the cloud where condensation has just taken place, the drops must be exceedingly small, and probably much the same size all along the edge around the cloud. For drops of this size at the distance of this cloud from the sun the diffraction band, say, is the third red one. Just inside of this cloud edge the particles have been formed for longer and have had a chance to grow to a larger size. For their size and this distance from the sun, the diffraction band, the fourth one (just beyond the third red), is blue. A little farther into the cloud the drops are still larger and are in the fourth red band for that size of drop. The central part of the cloud has still larger drops that fall in the fifth blue band. Therefore, the outer edge of the cloud has a rim of red, next comes a strip of blue and then another strip of red, while the central portion of the cloud is bluish and greenish.

The irregular intermixture of colors on the brilliant margin of a forming cumulus cloud may be explained on the same basis. The droplets just forming are not so large as those that have formed a few minutes before, and, therefore, while the angular distance from the sun may be such as to put this portion of the cloud in a red band for the droplets just formed, those a little larger even though they may be at the same angular distance from the sun are in the next blue or green band.

[2] See W. J. Humphreys, Optics of the Air, Jour. Franklin Inst., Nov., 1919, pp. 654-655.

MEASUREMENT OF WATER IN CLOUDS.

By L. F. RICHARDSON.

[Abstract from Proceedings of the Royal Society, Aug. 1, 1919, Series A, vol. 96, No. A674, pp. 19-31.]

Three types of clouds can be measured: I. Clouds into which an observer can enter. Several observers, notably Conrad and Wagner, have measured the water in clouds on mountains by drawing a measured volume of atmosphere over absorbing substances.[1] II. Clouds through which the sun's outline can be seen and which also exhibit coronae, as they often do. III. Uniform stratus, provided that some way can be found for measuring the size of the particles.

The second type of clouds has been investigated by means of a photometer which measures the variations of intensity of the sun's light in passing through cloud layers of different intensity. It has been suggested that the distance of visibility of an object through a mist is proportional to the diameter of the water particle. Conrad estimated that a terrestrial object was just visible when its intensity was about 1/77 that in clear air. This ratio of brightness of the object to its surroundings is represented by I/I_0. The observational results show that in various intensities of clouds through which the sun's disk could be seen, the volume of particles per horizontal area, the diameter of the particle, or $-2/3 \cos \zeta \log_e (I/I_0)$, is as follows; where ζ is the sun's zenith distance:

Description of cloud.	Volume of particles per horizontal area (diameter of particle).
Faintest cirrus	0.07.
Very thin cirrus	0.3, 0.3.
Ci or ci-stratus	0.04.
Very thin ci-stratus	
Ci-stratus, thin	0.06, 0.2, 0.8, 0.3, 0.5, 0.3, 0.8, 0.6, 0.4, 0.4, 0.8.
Ci-stratus (typical?)	
Ci-cumulus	0.6.
Ci-cumulus+ci-stratus	0.8, 0.9, 2.1.
Alto-cumulus	0.5.
Stratus, sun much dimmed, but still obvious at $\zeta=40°$.	2.5.
Stratus, sun's disk just visible at $\zeta=49°$	4.1.

It is pointed out that diffraction should be considered before this result can be relied upon.

In the case of heavier clouds, it is necessary to make use of the amount of transmitted light and the reflectivity of the earth's surface. In the case of certain rain clouds on the afternoon of May 24, 1918, it was found that the volume of liquid per horizontal cm.^{2} of cloud amounted to 24 diameters of the cloud droplets. This, it will be noted, is in accord with the observations of thinner clouds in the table above.—*C. L. M.*

[1] The first type is discussed by Hann's Meteorology, third edition (1915), p. 306. The moisture was obtained by drawing known volumes of air over absorbing substances, such as calcium chloride or pumice stone saturated with sulphuric acid. It was found in this way that in various types of clouds on mountains the moisture content varied from 1.6 gram per cubic meter, where it was possible to see 50 meters through the cloud, to 4.5 gram per cubic meter where the radius of vision was limited to 20 or 25 meters. It was found that when the water particles are about 0.01 mm. in diameter, and the water-content of the cloud is from 1 to 2 grams per cubic meter, the number of drops is between 200 and 500 per cubic centimeter.—C. L. M.

SOME OBSERVATIONS ON A FREE-BALLOON FLIGHT MADE FROM ABERDEEN PROVING GROUND, MD., JUNE 3, 1920.

By DON MCNEAL, 2d Lieut. Meteorological Section, Signal Corps.

As a part of the course in pilots' training, a free balloon flight was made from Aberdeen Proving Ground, Md., June 3, 1920. Existing and indicated meteorological conditions on this day gave promise of anything but ideal weather for a flight of this kind. For three days preceding, this section of the country had watched the slow eastward drift of a trough of low pressure from the west and northwest, which had been attended by general rains and thunderstorms. On the morning of the 3d, the center of the trough extended from the St. Lawrence Valley southwestward over New York, Pennsylvania, West Virginia, Tennessee, and on to the Gulf.

The day opened fair, with only a few Ci.St. and A.Cu. clouds visible. These forms were moving from the west and southwest respectively. The pilot balloon observation, taken at 7:29 a. m., showed a west surface wind, veering quickly into WNW. and NW. winds, and above 8,500 feet, backing again into the west. The velocities were moderate at all levels, increasing only slightly with altitude.